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An Overview of the Committee for the Testing of Body Armor Materials for Use by the U.S. Army (Phases I, II, and III)

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**An Overview of the
Committee for the Testing of Body Armor
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(Phases I, II, and III)**

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Interceptor Body Armor

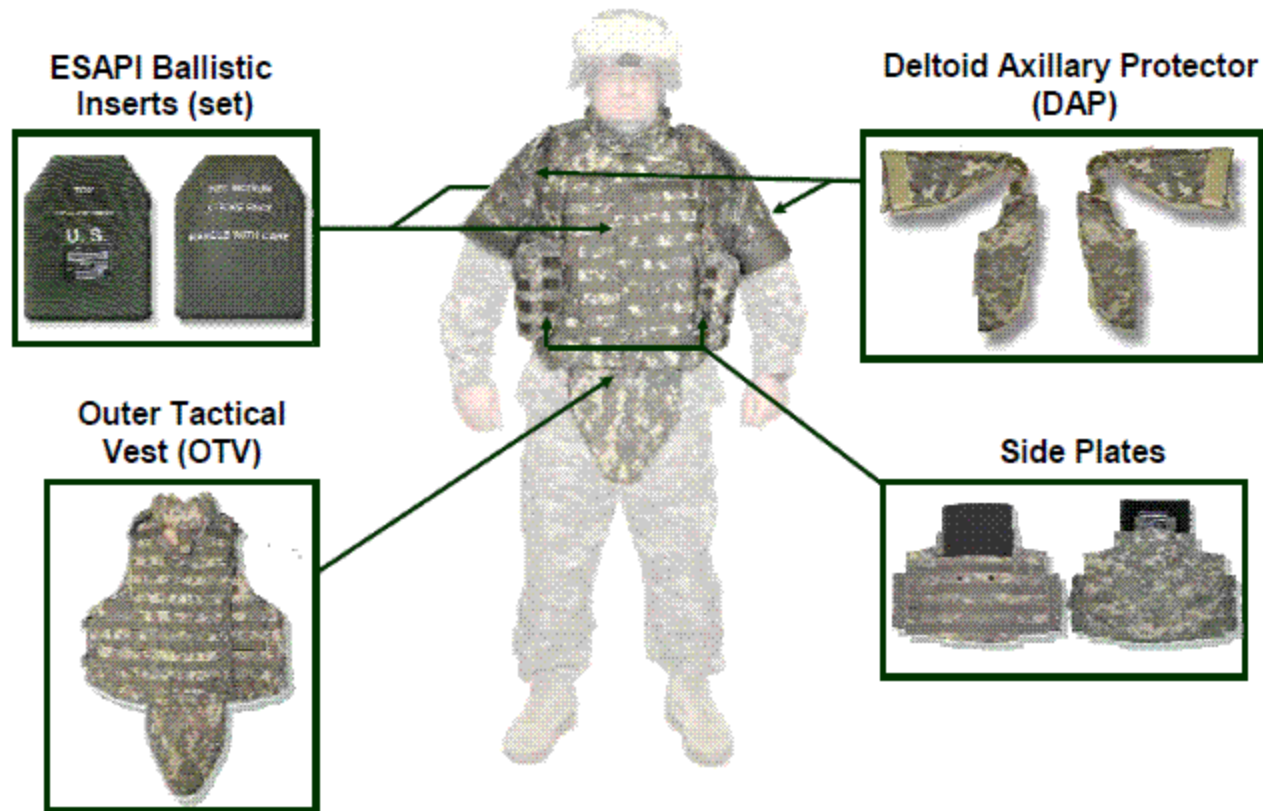
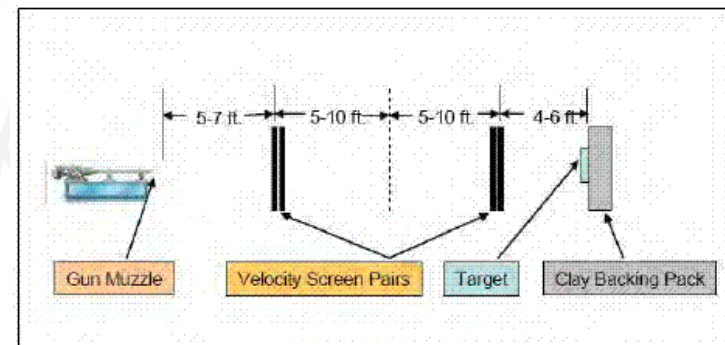


Figure 1. Interceptor Body Armor

Body Armor Testing, In Brief

- Before awarding contracts to buy body armor, DoD conducts “first article testing” or FAT
- Goal is to determine whether product meets purchase specifications
- For body armor, it is a destructive ballistic test
 - I.e., representative armor is shot at under various conditions



Clay as Recording Medium

- Test consists of mounting “shoot pack” on clay backing
- Use of clay based on Prather et al. (1977) study which found clay measurements could be “*correlated to tissue response for use in characterizing both the penetration and deformation effects of ballistic impacts on soft body armor materials.*”
- Changes in clay formulation over time have resulted in extensive effort to try to maintain test clay consistency



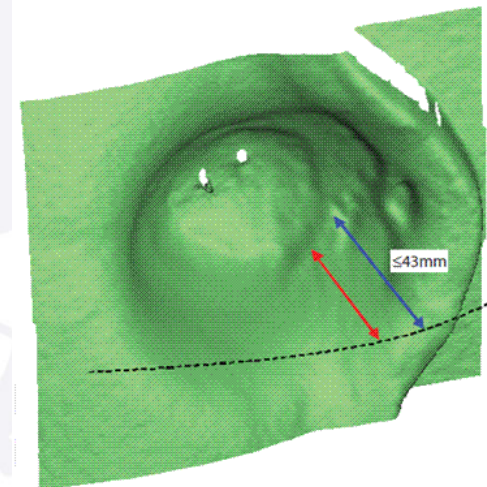
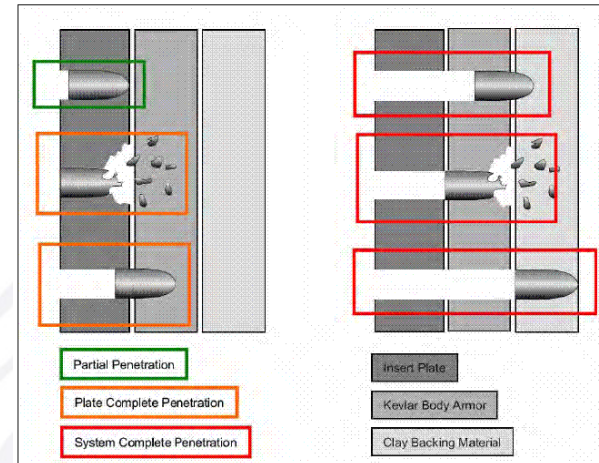
Source: Phase II Report on Review of the Testing of Body Armor Materials for Use by the U.S. Army, The National Academies, April 22, 2010.

- Penetration

- Resistance to projectiles fired at a constant velocity
- May be partial (plate, Kevlar) or complete (bullet or bullet fragments into clay backing)

- Back face deformation (BFD)

- BFD is the depth of the crater left in the clay after impact
- Surrogate measure for blunt force trauma





Measuring BFD: Digital Caliper

- Digital caliper used to measure BFD has several shortcomings, including
 - If deepest location in the clay indent is displaced from the aim point, must estimate original clay surface at the impact point
 - Caliper subject to operator judgment because one must measure a soft, deformable surface by barely touching and yet not disturbing the clay
- Precision (standard deviation) for measuring etched metal gage block on order of 0.1 mm; for BFD in soft clay medium on order of 1 mm

Laser Profilometry/Interferometry

- Laser used to take three dimensional measure of clay surface before and after test
 - Differences of two surfaces used to measure BFD
- Benefits:
 - Does not require contact with clay
 - Measurements collected over whole surface
- However, system more complicated and costly
- In Phase III, questions about accuracy (bias) arose





Body Armor Testing Issues

- Testing protocols differ across DoD
- Army protocol not statistically based
 - DoD IG: *“standardization of body armor testing and acceptance will ensure that Service members receive body armor that has been rigorously tested and will provide uniform protection in the battlefield”*¹
- Clay-based testing:
 - Clay formulation has changed over time, resulting in a formulation that is temperature sensitive
 - How much variation in test results attributable to variation in test conditions and how much due to plate variation unknown
 - Scientific connection between clay test results and protection of human beings somewhere between not well known and unknown

¹ “DoD Testing Requirements for Body Armor”, Inspector General, United States Department of Defense, Report No. D-2009-047, January 29, 2009.



- Three-phase study
 - Phase I
 - Six-week effort
 - Report released January 2010
 - Phase II
 - Three month effort
 - Report released May 2010
 - Phase III:
 - Intended to be a 14-month effort
 - Report released May 2012



- DOT&E tasked the committee to:
 - “...comment on the validity of using laser profilometry/laser interferometry techniques to determine the contours of an indent made by a ballistic test in a non-transparent clay material at the level of precision established in the Army’s procedures for testing personal body armor.”
 - “...provide interim observations regarding the column-drop performance test described by the Army for assessing the part-to-part consistency of a clay body used in testing body armor.”



- “The digital caliper is adequate for measurements of displacements created in clay by the column-drop performance test...”
- “Surface profilometry by a laser... is a valid approach for determining the contours of an indent in a nontransparent clay material at a level of precision adequate for the Army’s current ballistic testing of body armor.”



- DOT&E tasked the committee to:
 - “...consider in greater detail [than in Phase I] the validity of using the column drop performance test described by the Army for assessing the part-to-part consistency of a clay body within the level of precision that is identified by the Army test procedures.”
 - “The final report will document the committee’s findings pertaining to...the appropriate use of statistical techniques (e.g., rounding numbers, choosing sample sizes, or test designs) in gathering the data.”



- Total of 60 plates tested spread over a combination of plate sizes, environmental conditions, and shot order
- Passing standards:
 - Penetration:
 - 90 percent lower confidence bound for the probability of no penetration [$\Pr(nP)$] is greater than 0.9 (first shot) and greater than 0.7 (second shot)
 - BFD:
 - First shot: one-sided 90% upper tolerance limit for BFD must be less than 44.0 mm with 90 percent confidence
 - Second shot: one-sided 80% upper tolerance limit for BFD must be less than 44.0 mm with 90 percent confidence



Phase II Recommendations: Clay-Related

- “...expedite the research necessary both to quantify the medical results of blunt force trauma on tissue and to use those results as the updated mathematical underpinnings of the back face deformation (BFD) body armor testing methodology.”
- “The Army should develop ballistic testing performance specifications and properties that will lead to a short-term, standard replacement for the current Roma Plastilina #1 oil-based modeling clay.”
- “Since oil-based modeling clay is time and temperature sensitive, a post-drop calibration test is needed to validate that the clay remains within specification at the end of a body armor test.”



Phase II Recommendations: Statistical Methodology

- “The committee unequivocally supports the concept of a statistically based test protocol...”
- “...the Army should quickly develop and experiment with a gas gun calibrator, or equivalent device...to estimate as accurately as possible the variation of back face deformation measurements both within a given box and between boxes, under realistic testing conditions using existing test protocols.”
- “...the results of the experiments and analyses proposed in this report, should be used as due diligence to carefully and completely assess the effects, large and small, of the proposed statistically based protocol before it is formally adopted across the body armor testing community.”



- DOT&E tasked the committee to:
 - Develop ideas for revising/replacing the Prather study methodology
 - Provide a roadmap to reduce variability of clay processes and how to migrate from clay to future solutions
 - Within the time and funding available, review and comment on methodologies and technical approaches to military helmet testing



Some Phase III Recommendations

- “The Army medical and scientific testing communities should adequately fund and expedite the research necessary to experimentally and epidemiologically quantify the physiologic and medical impact of blunt force trauma on the body from both ballistic and blast threats to soldiers.”
- “The Office of the Director, Operational Test and Evaluation, and the Army should continue to expedite the development of a replacement for the current Roma Plastilina #1 oil-based modeling clay that can be used at room temperature.”



Some Phase III Recommendations

- “An organization such as the National Institute of Standards and Technology should conduct a controlled study to determine the most reasonable and consistent Faro smoothing settings to be used while measuring backface deformations (BFDs) in body armor testing. Similarly, any other software selections that could cause relevant changes to BFD measurements should be studied. Corresponding values for the precision and accuracy of each software setting will need to be quantified.”